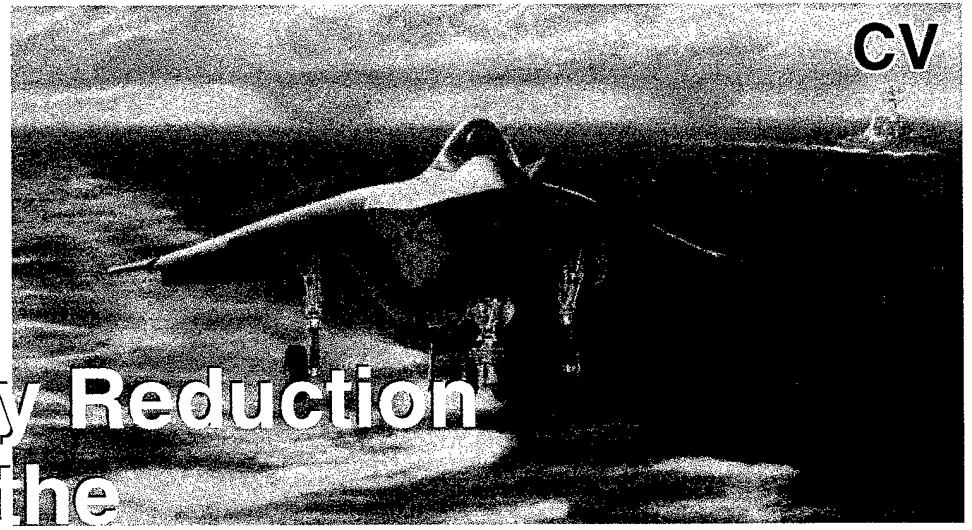
JOINT STRIKE FIGHTER

JSF

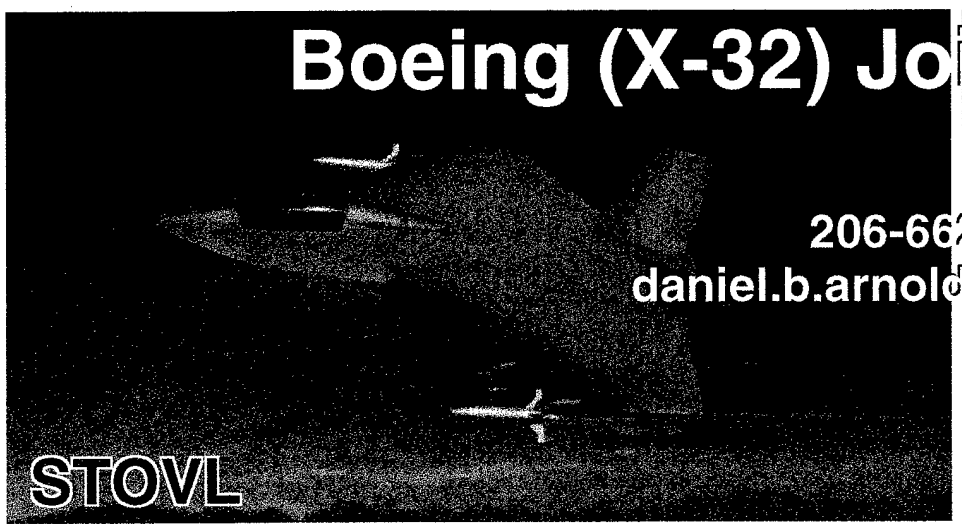
BOEING

Joint Strike Fighter
Multi-Service Weapon System



Vulnerability Reduction in the Boeing (X-32) Joint Strike Fighter

206-662-0762
daniel.b.arnold@boeing.com



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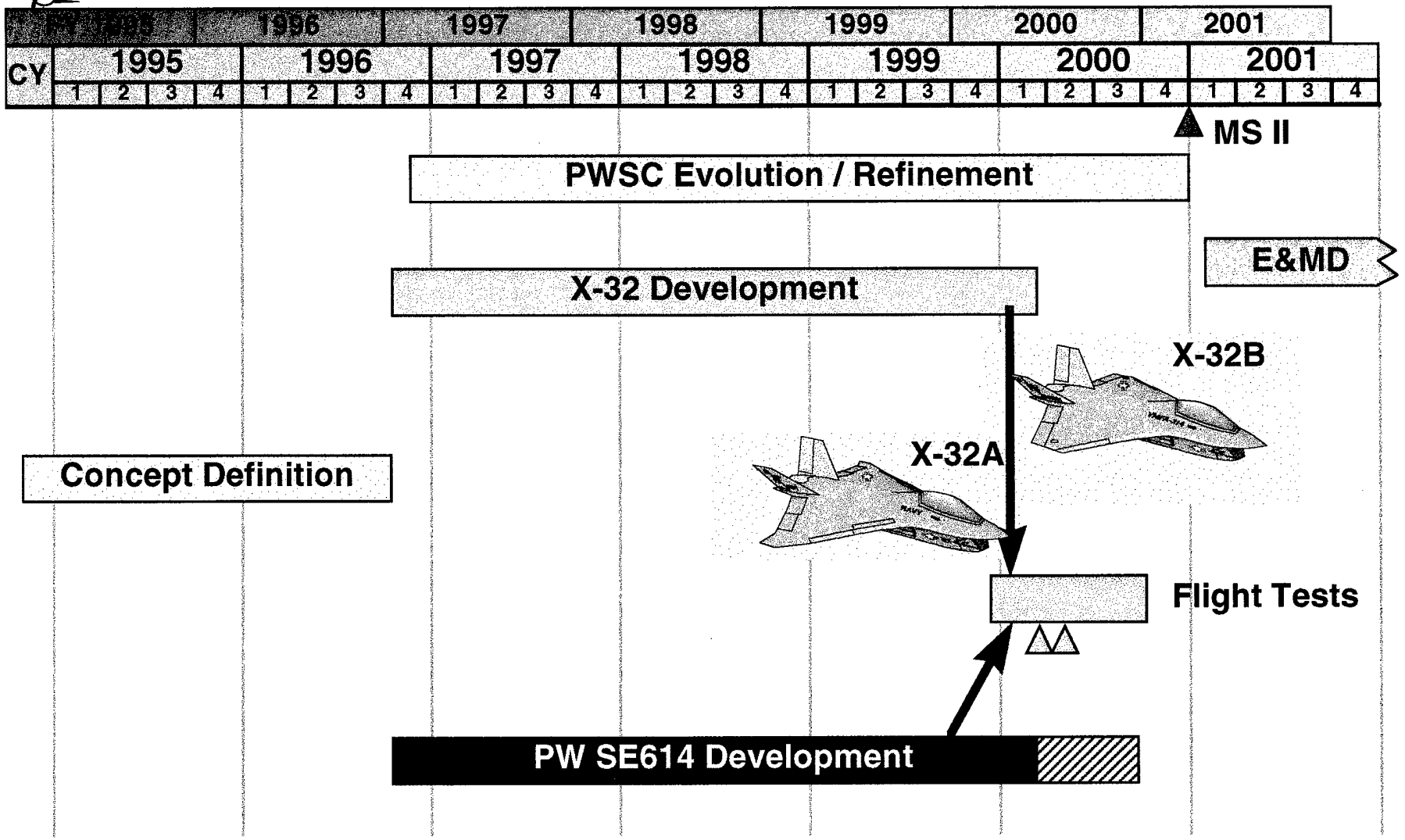
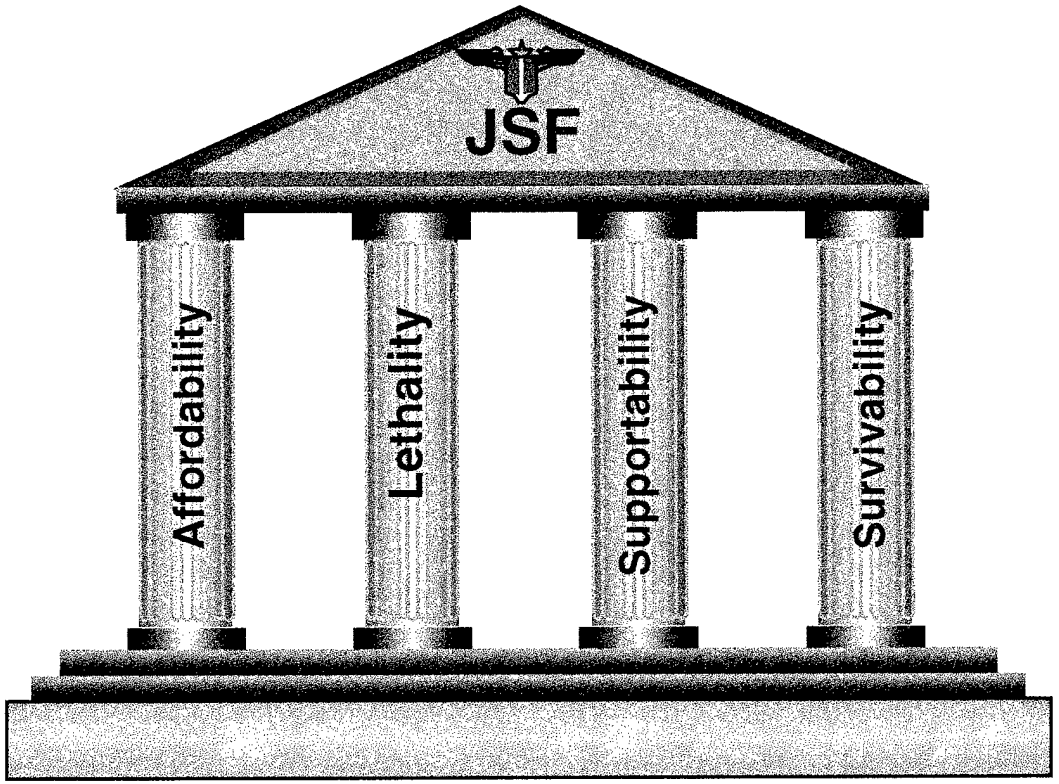
Concept Demonstration Program Schedule



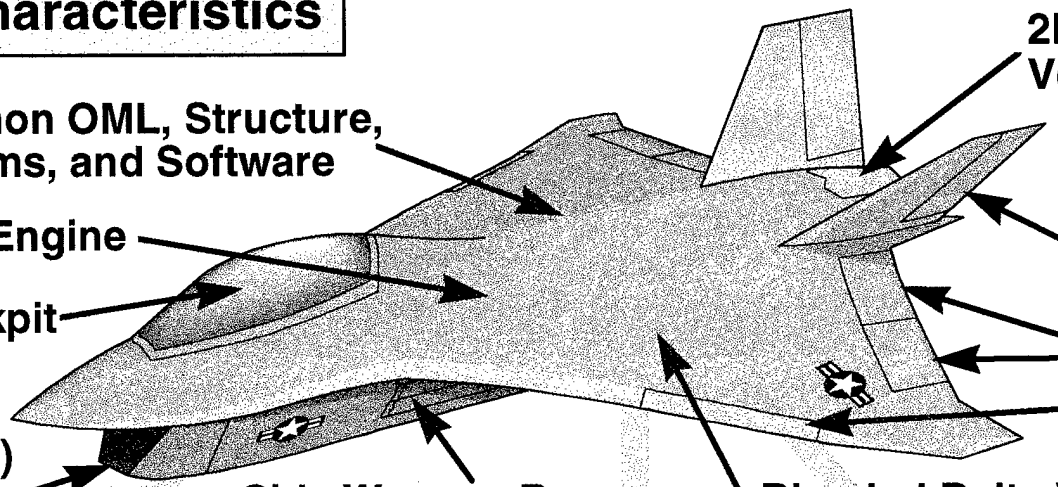
Requirements and Objectives

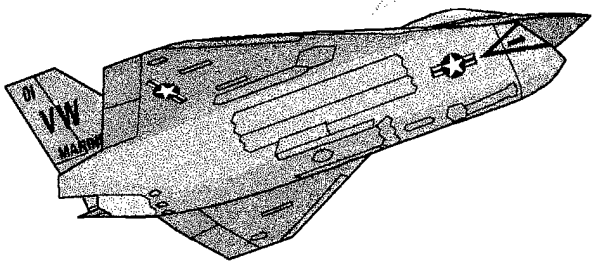
- Multi-Service Weapon System
  - Affordable
  - Operational Capability to Meet Warfighter Needs



Multi-Service Design Concept

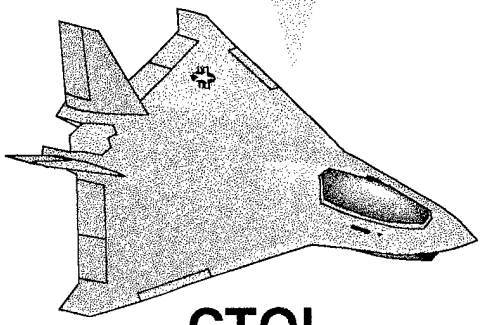
Common Characteristics





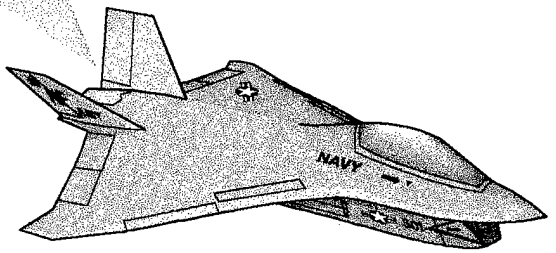
STOVL

- Wingtips Removed
- Direct Lift Nozzles



CTOL

- Internal 20mm Gun
- Lightweight Arresting Hook



CV

- Dual Nose Gear, Arresting Hook
- Higher Strength Gear

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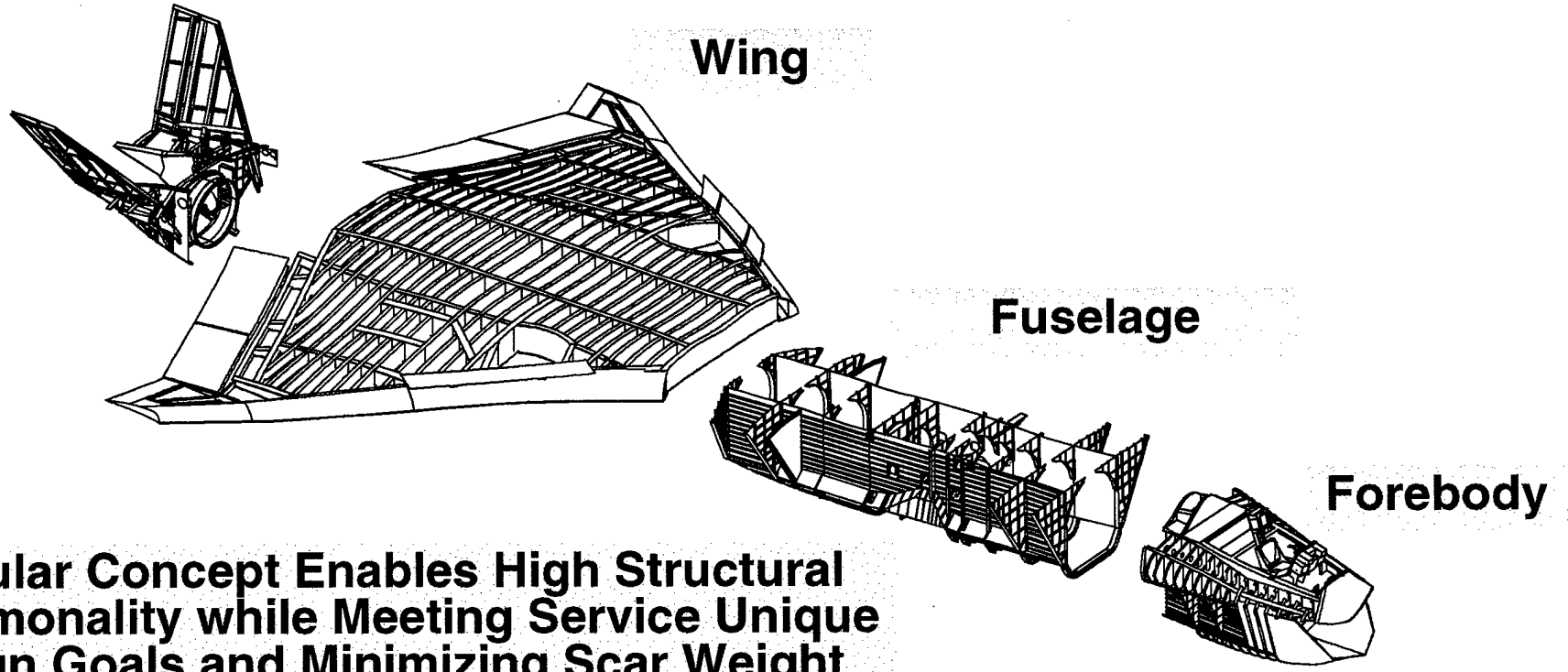
Modular Concept

JSF BOEING

JOINT STRIKE FIGHTER
U.S. NAVY U.S. MARINE CORPS U.S. AIR FORCE

Aftbody / Empennage

- 4 Major Components



- Modular Concept Enables High Structural Commonality while Meeting Service Unique Design Goals and Minimizing Scar Weight
- Multi-Service Common Engine
- 99-100% Common Cockpit, Avionics, Software, Subsystems

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JOINT STRIKE FIGHTER

JSF

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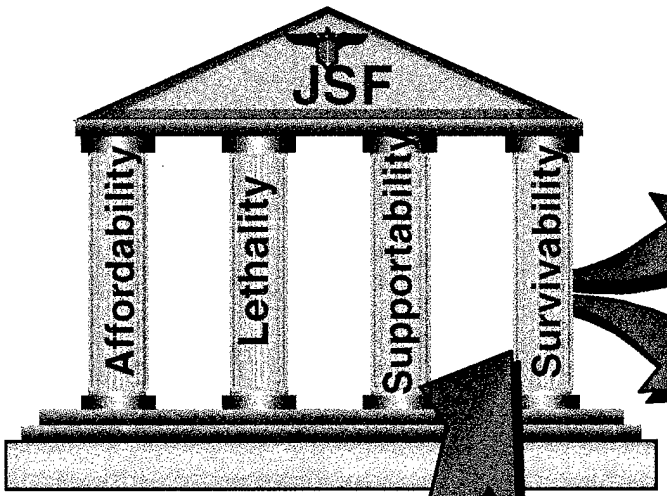
Survivability

The JSF Configuration is a Balance of Vulnerability and Susceptibility

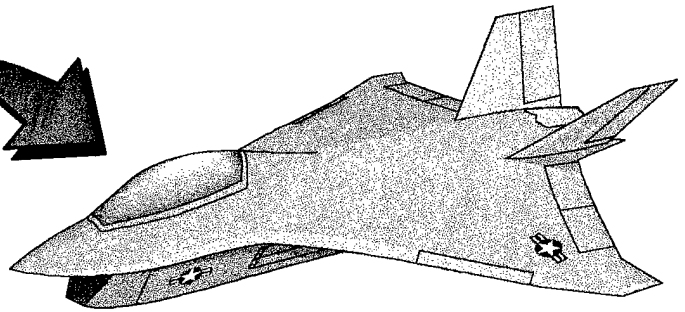


Vulnerability

- -Redundancy
- -Shielding
- -Toughness
- -Separation
- -Clustering

Susceptibility

- -Speed
- -Range
- -Signature
- -Maneuverability
- -Altitude



Survivability is the Capability to Complete the Missions, Return the Aircraft Safety and Rapidly Deploy the Aircraft for the Next Mission

JOINT STRIKE FIGHTER

JSF

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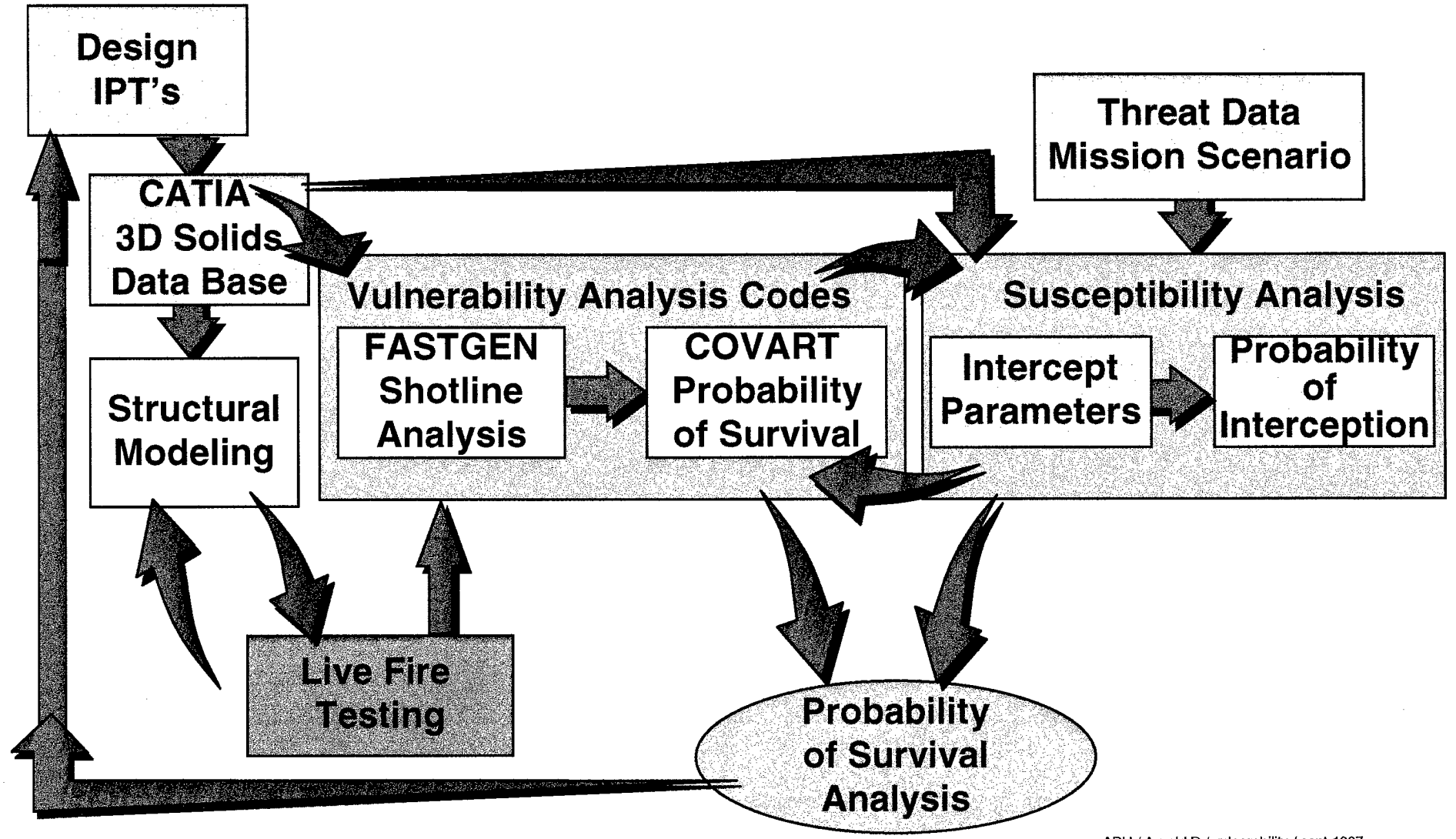
Balance Between Susceptibility and Vulnerability



JOINT STRIKE FIGHTER

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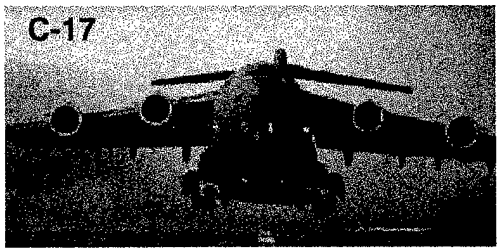
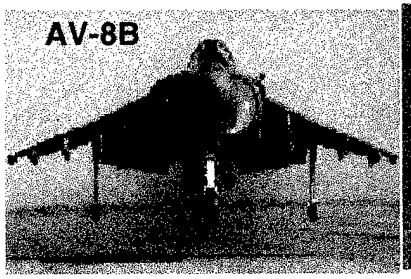
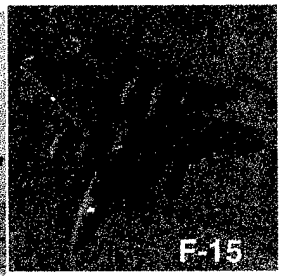
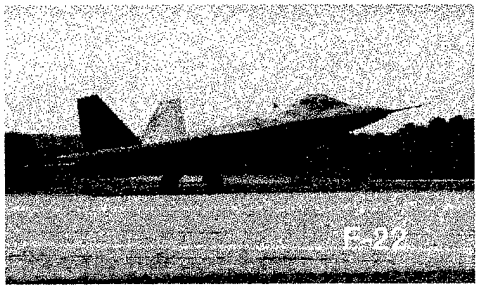
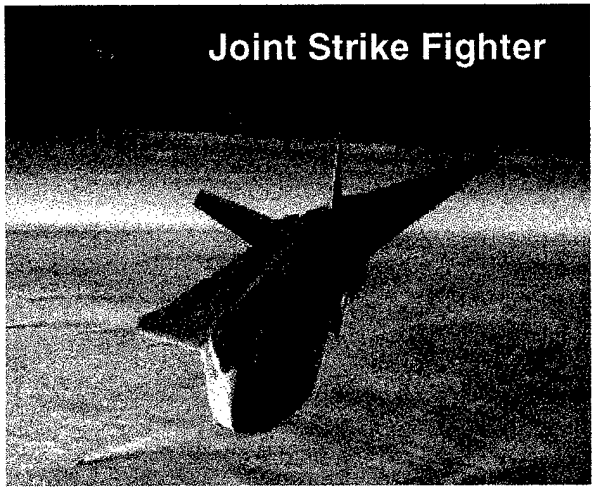
Lessons Learned Applied to Boeing's JSF PWSC

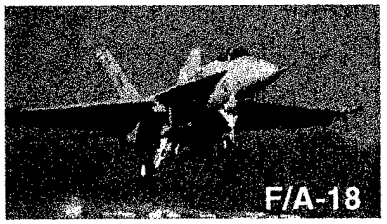


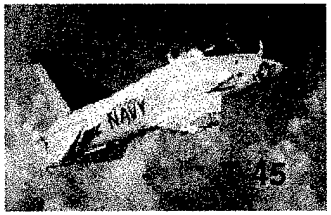


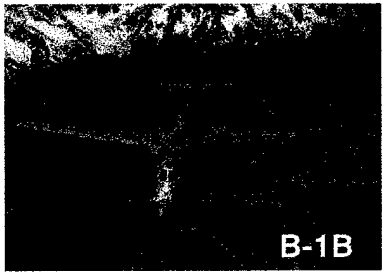


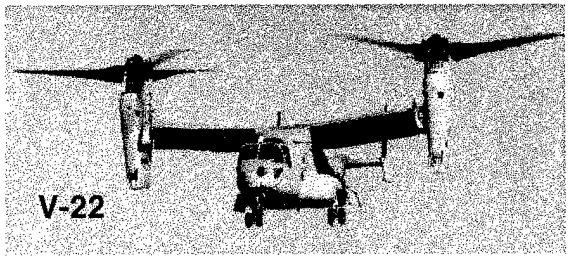












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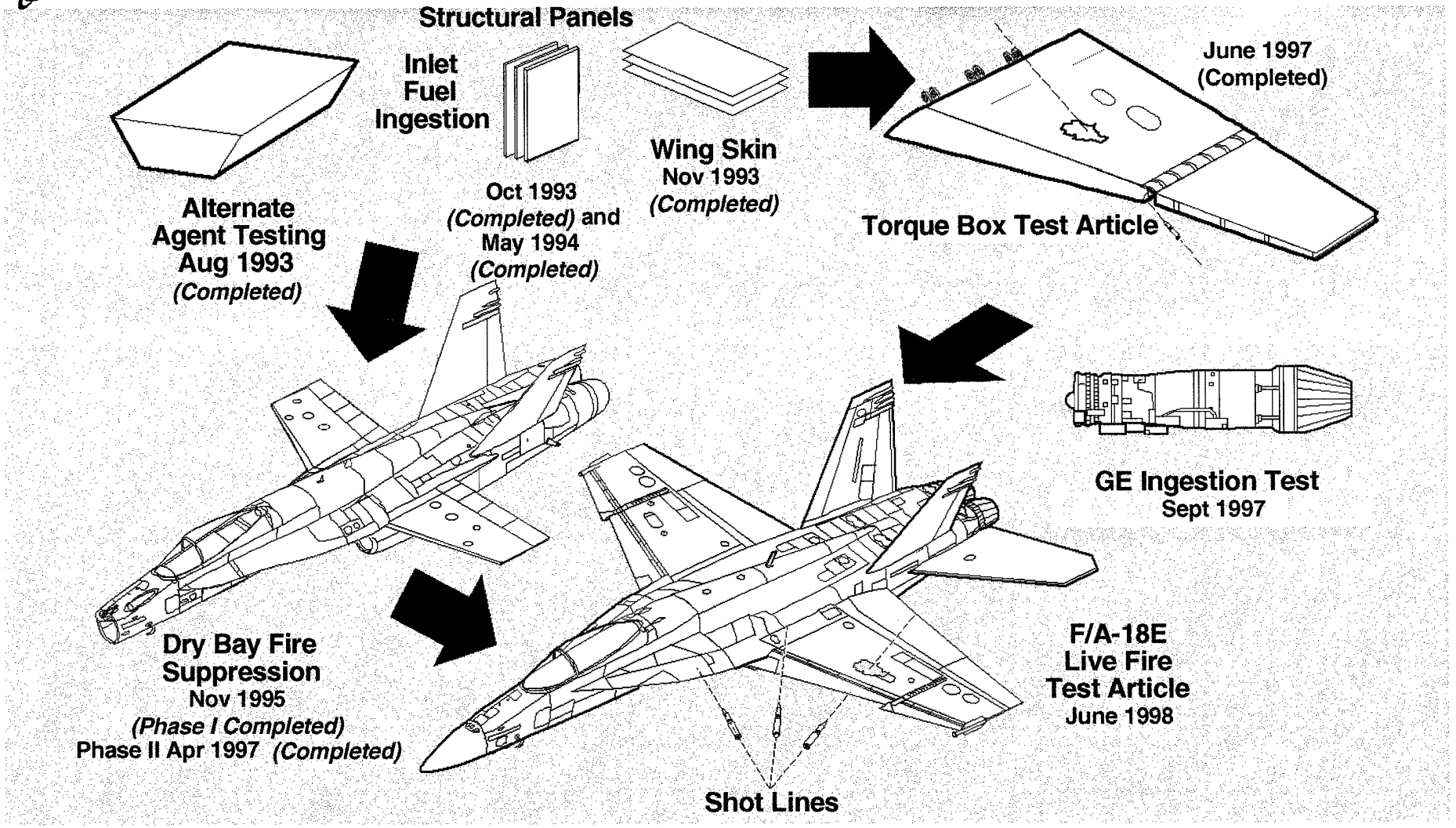
Building Block Approach for Live Fire Testing



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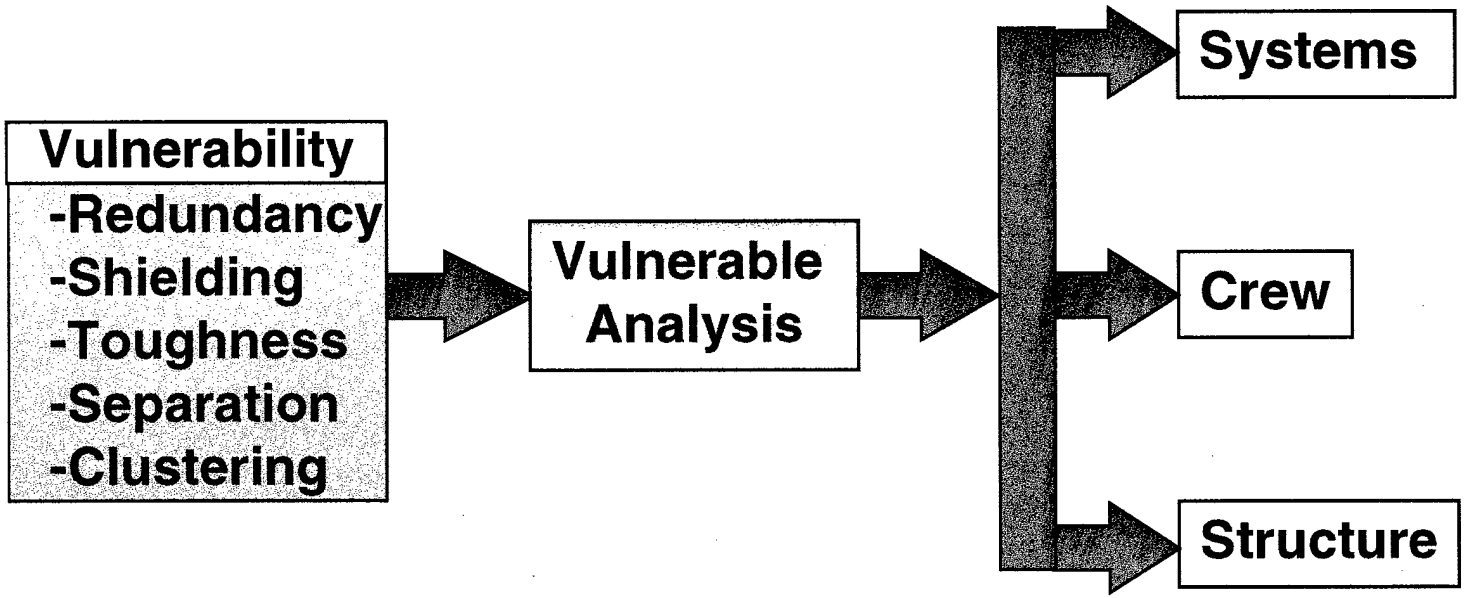
Vulnerability Analysis -Approach



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Boeing's Vulnerability Analysis Methods

JOINT STRIKE FIGHTER
JSF
BOEING

Failure Modes & Effects Analysis Kill Tree

Threat Characterization

Susceptibility Engagement Parameters

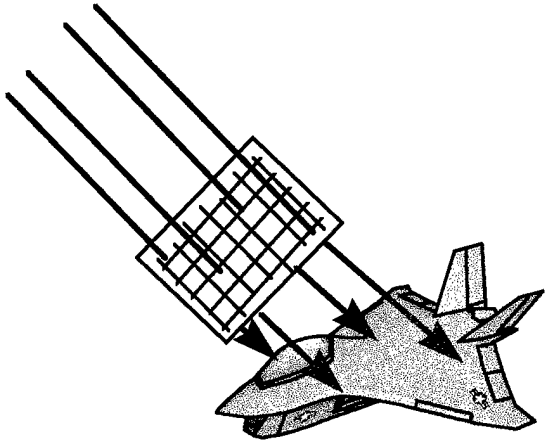
Tri-Service Standard Vulnerability Model

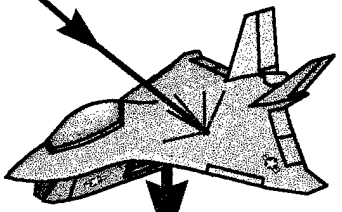
Develop Shotline Data Files

Vulnerable Area Analysis

Warhead Fragments & API Projectiles

HEI Projectiles





Output Data

Aircraft Total Vulnerable Area
Tabulated Component Vulnerable Areas

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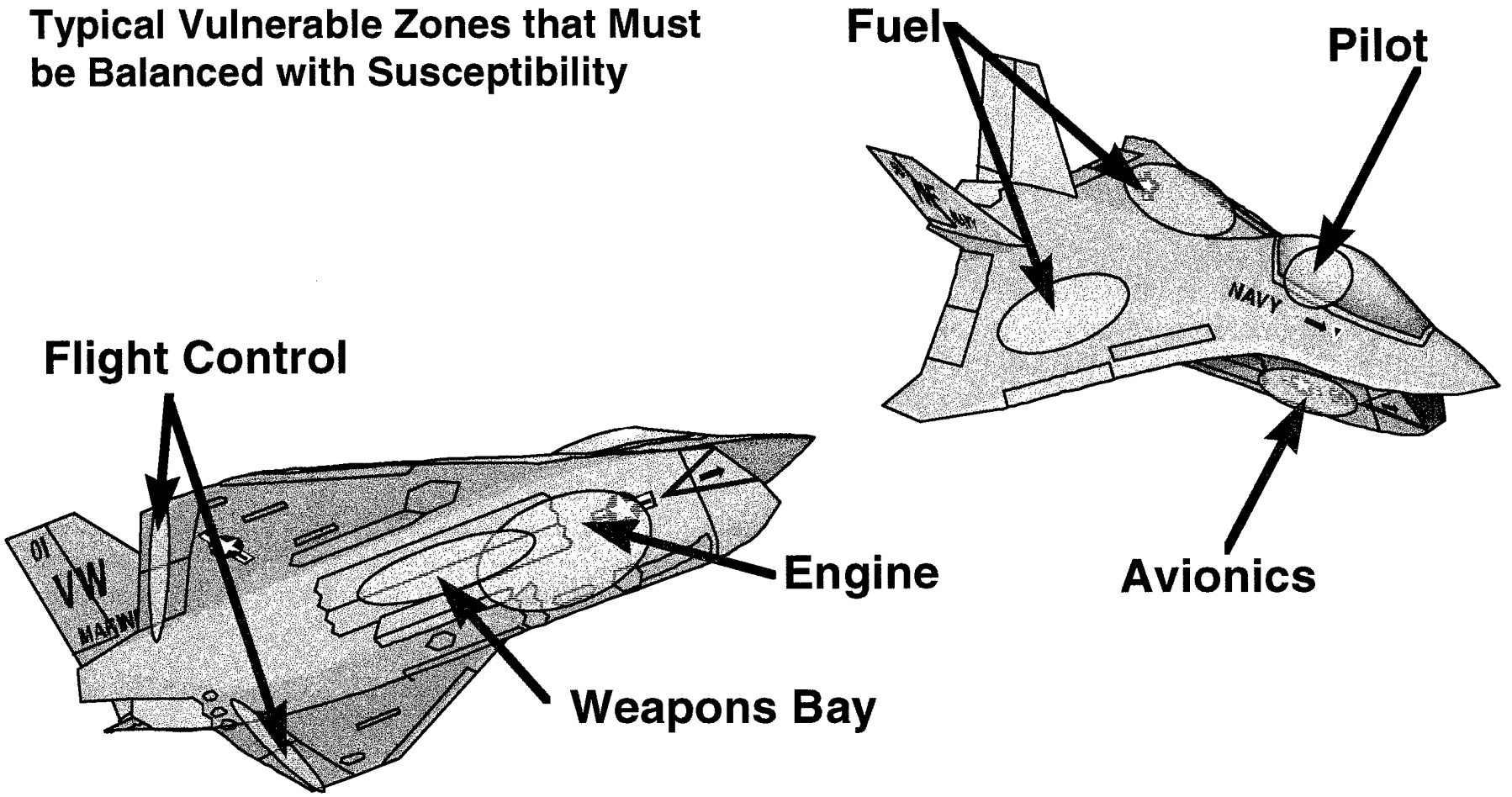
Vulnerable Zones of Aircraft

Typical Vulnerable Zones that Must be Balanced with Susceptibility



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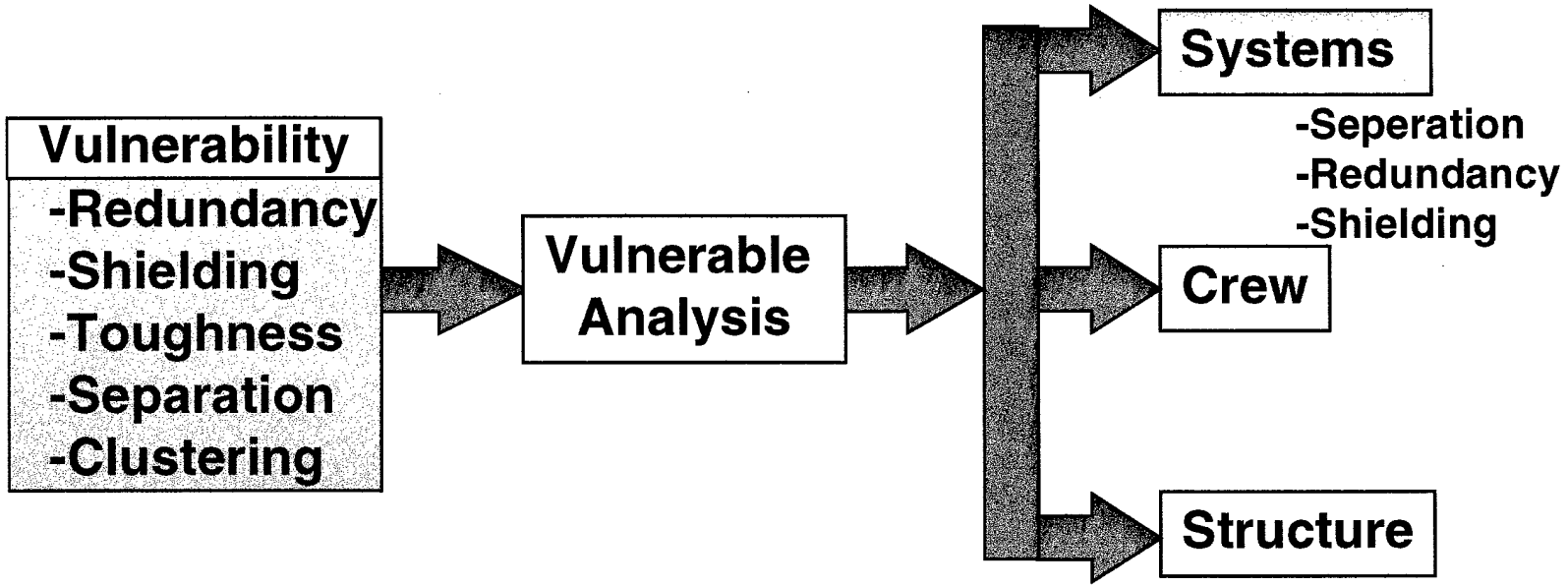
Vulnerability Analysis -Approach



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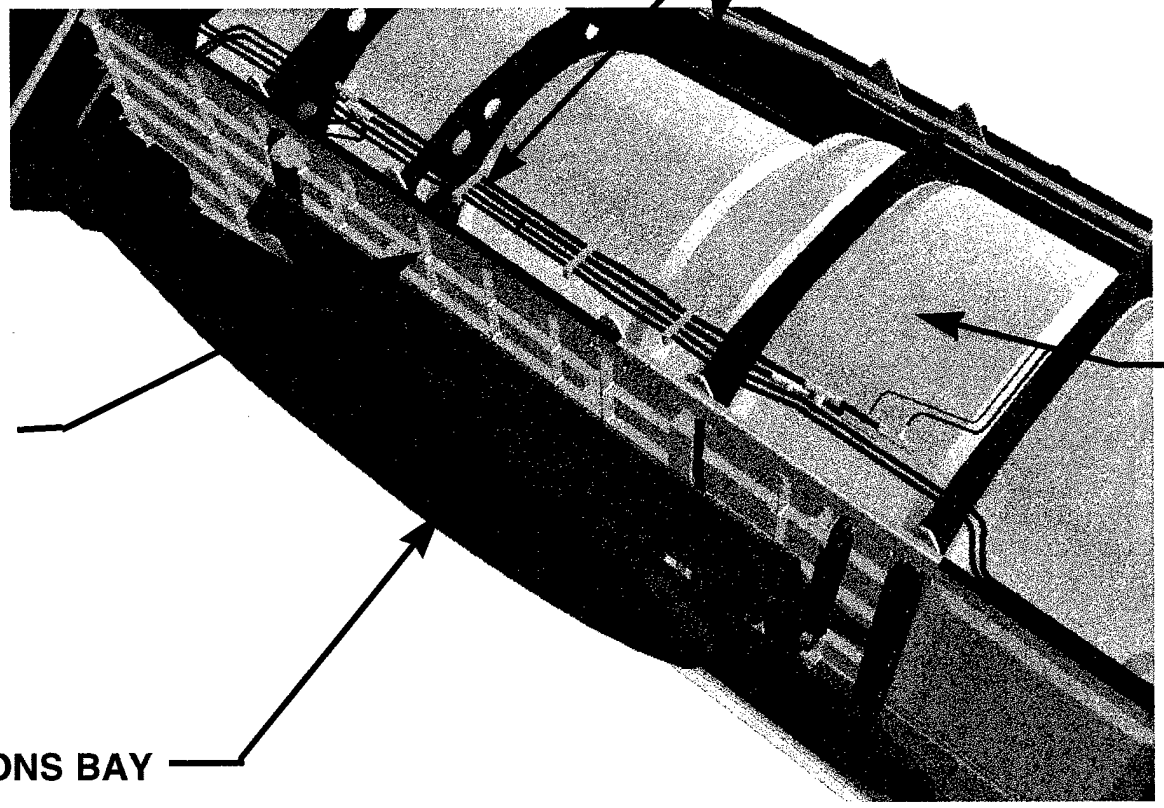
TYPICAL SHIELDING AND SEPARATION



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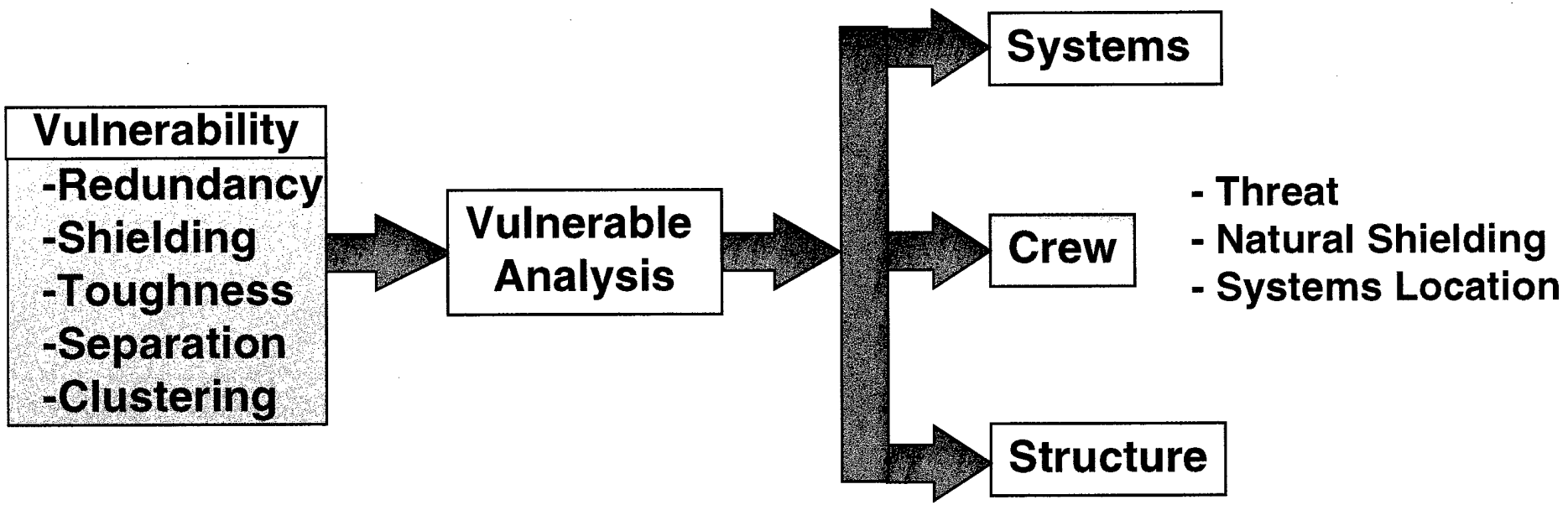
Crew Protection Design Approach



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JOINT STRIKE FIGHTER

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Develop Shotline Format Model Digitally from CATIA Design Model

Pilot & Seat Assembly

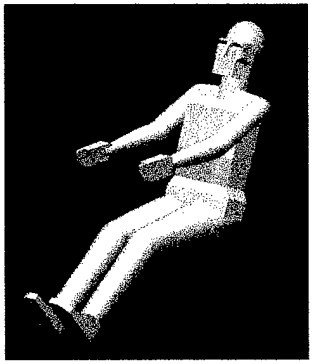
Aircraft Design

CATIA Models

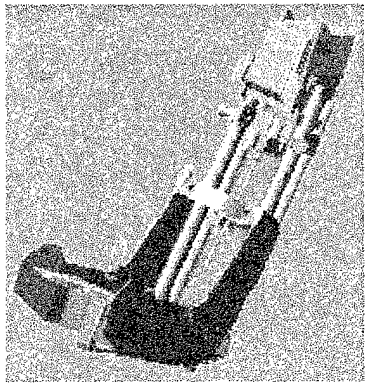
Convert Data to Shotline Vulnerability Model

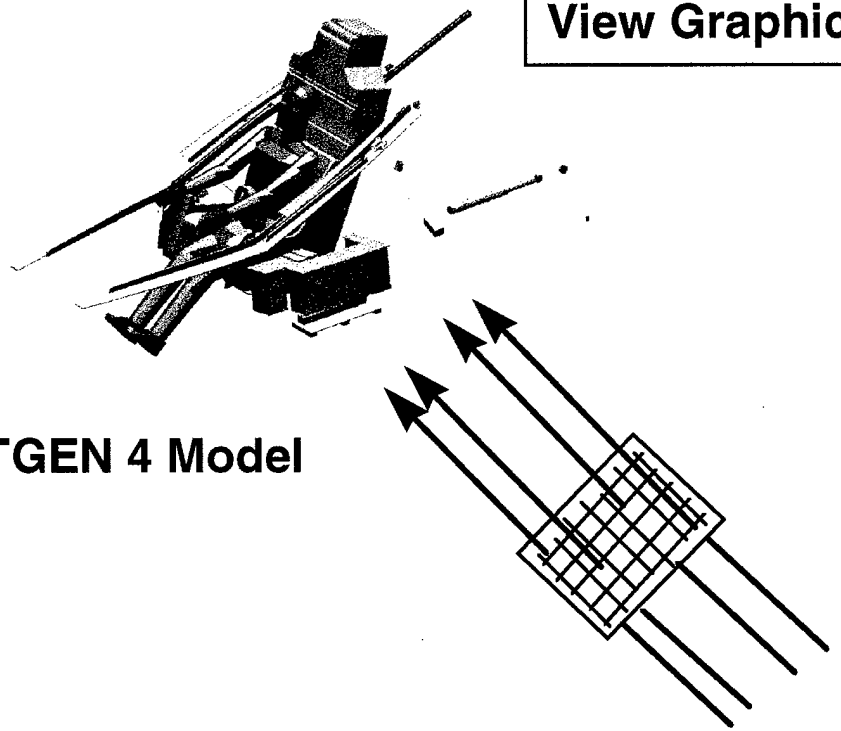
Tri-Service Standard Vulnerability Model

View Graphics



CATIA Model Pilot





FASTGEN 4 Model

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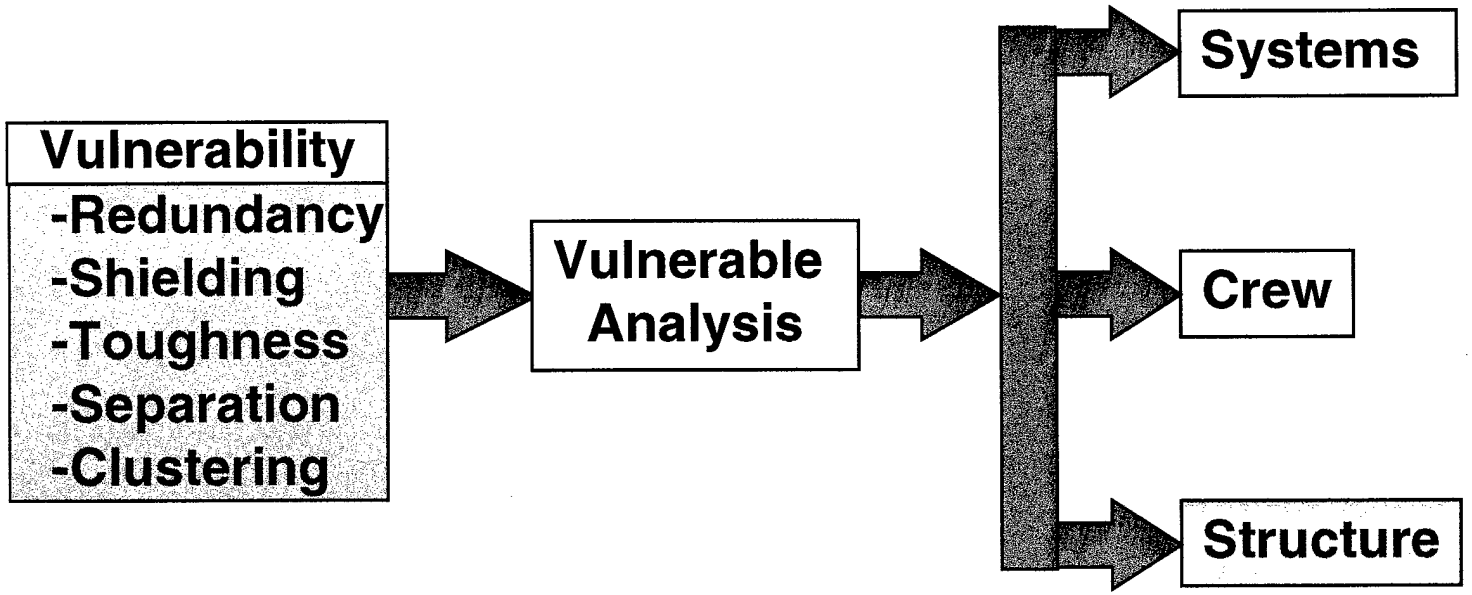
System Design Approach



- Finite Element Modeling
- Redundancy Vs Single Load Path
- Energy Absorption
- Hydraulic Ram

JOINT STRIKE FIGHTER

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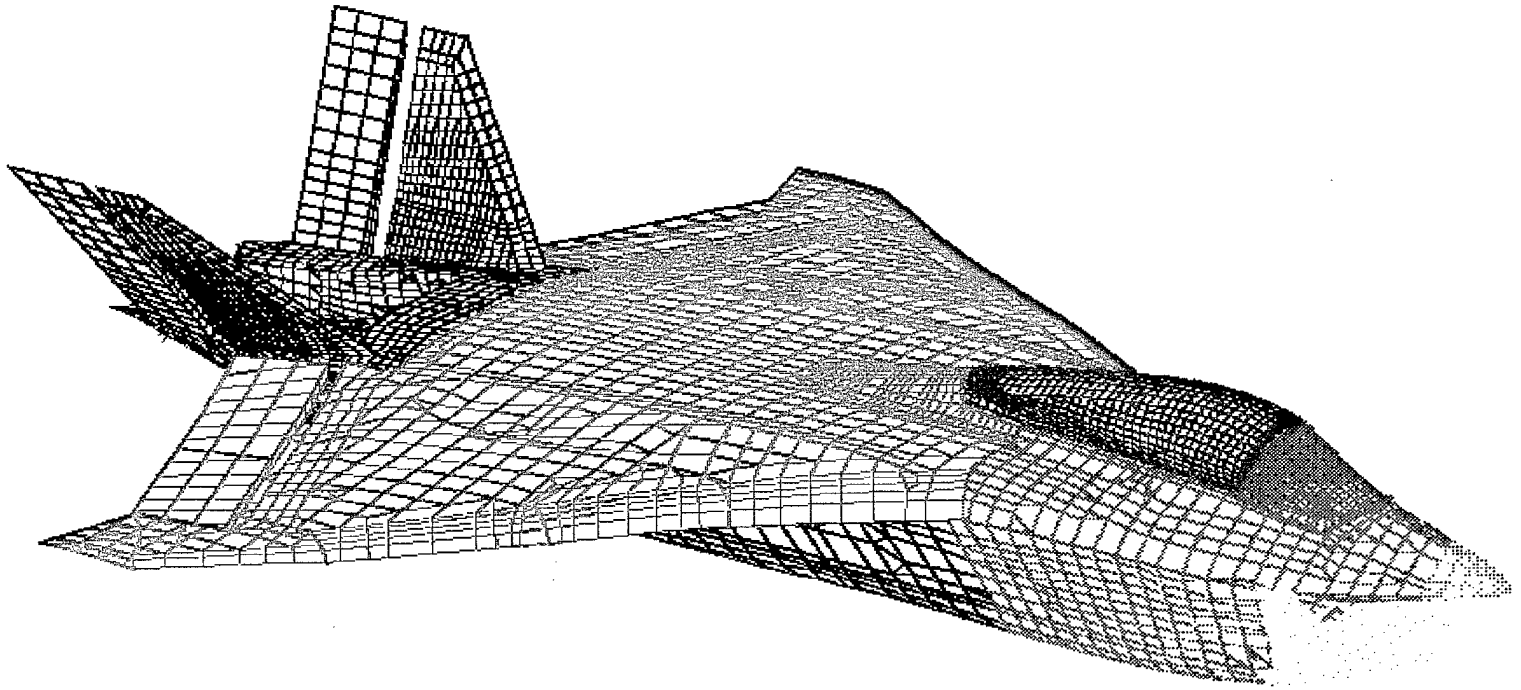
Finite Element Model



JOINT STRIKE FIGHTER

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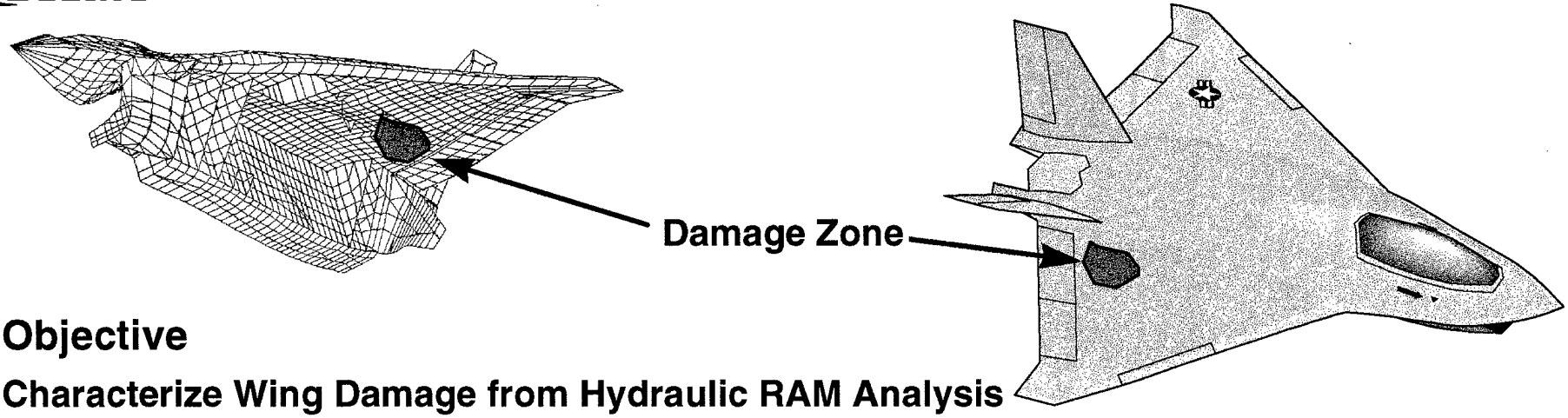
PWSC Wing Structure Vulnerability Analysis



Objective

Characterize Wing Damage from Hydraulic RAM Analysis

Approach:

- ❒ **Loads – Flight Condition Symmetrical Pull-up at Impact and Residual Strength**
- ❒ **Assume Hydrodynamic Ram Eliminates Internal Spars and Associated Skins**
- ❒ **Spars and Skin Eliminated from FEM Incrementally**
- ❒ **FEM Principal Skin Strains Compared against Wing Material Allowables.**

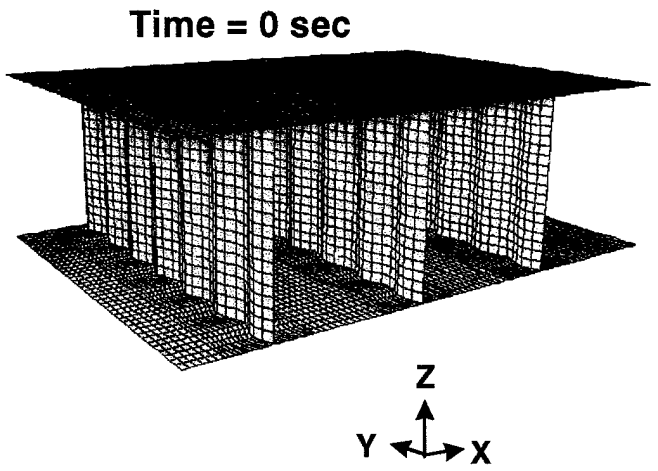
Results

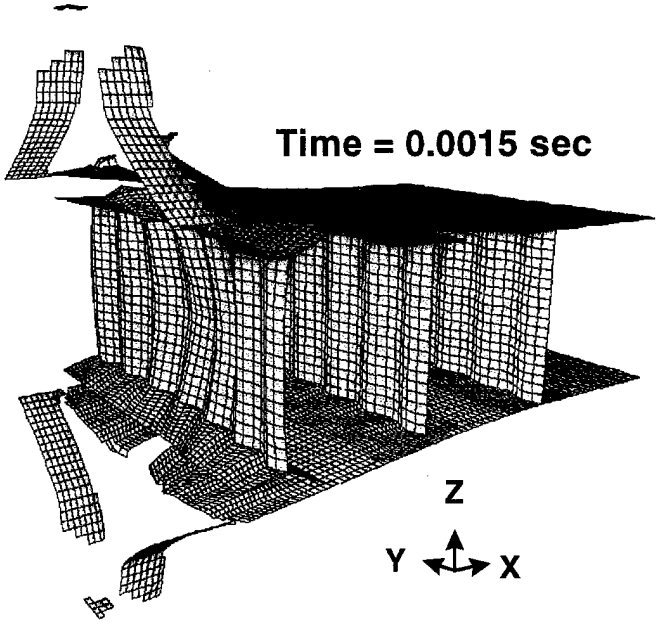
- ❒ **Number of Spars which can be Lost and Maintain Partial Structural Integrity**

Analysis used prior to live fire testing

Hydraulic RAM Structural Response

Wing Box Structure
Energy Equivalent to 30 mm HEI

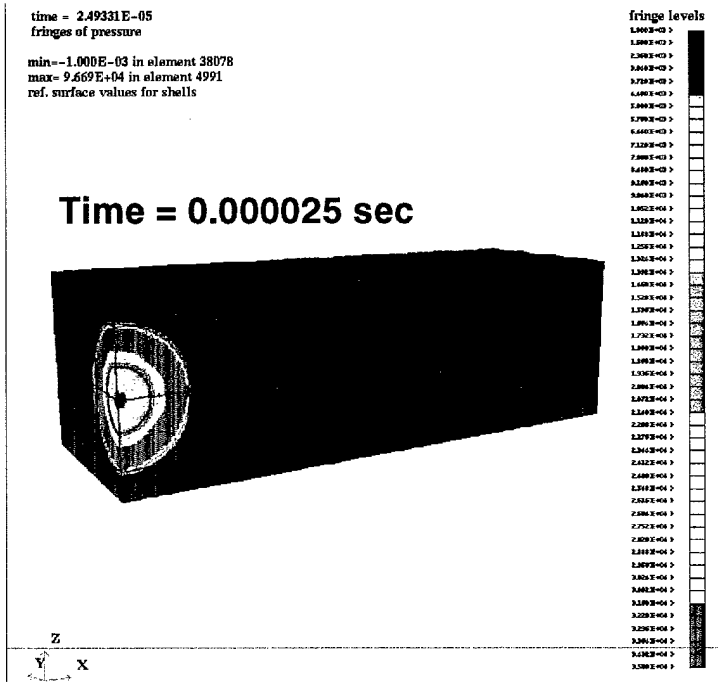




JOINT STRIKE FIGHTER

Hydraulic Ram Shock Pressures

Wing Box Structure
Energy Equivalent to 30 mm HEI



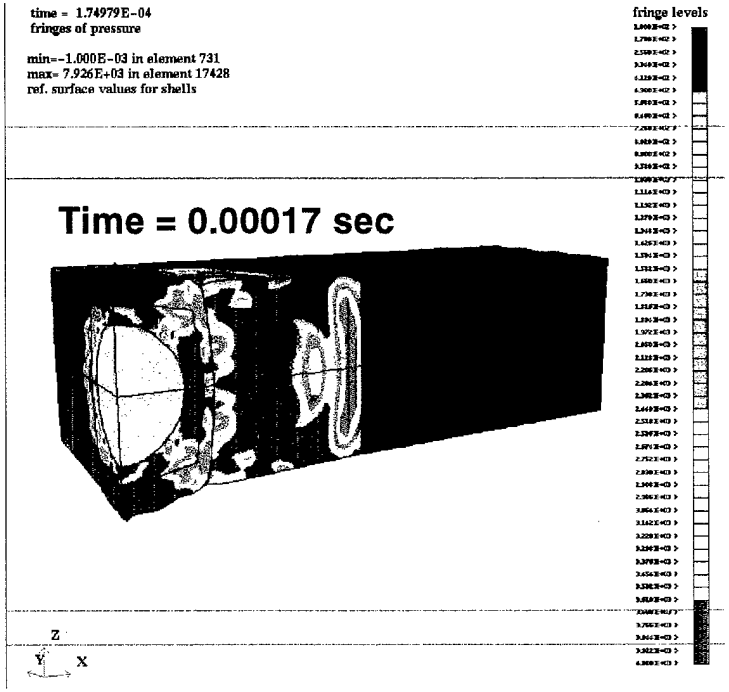
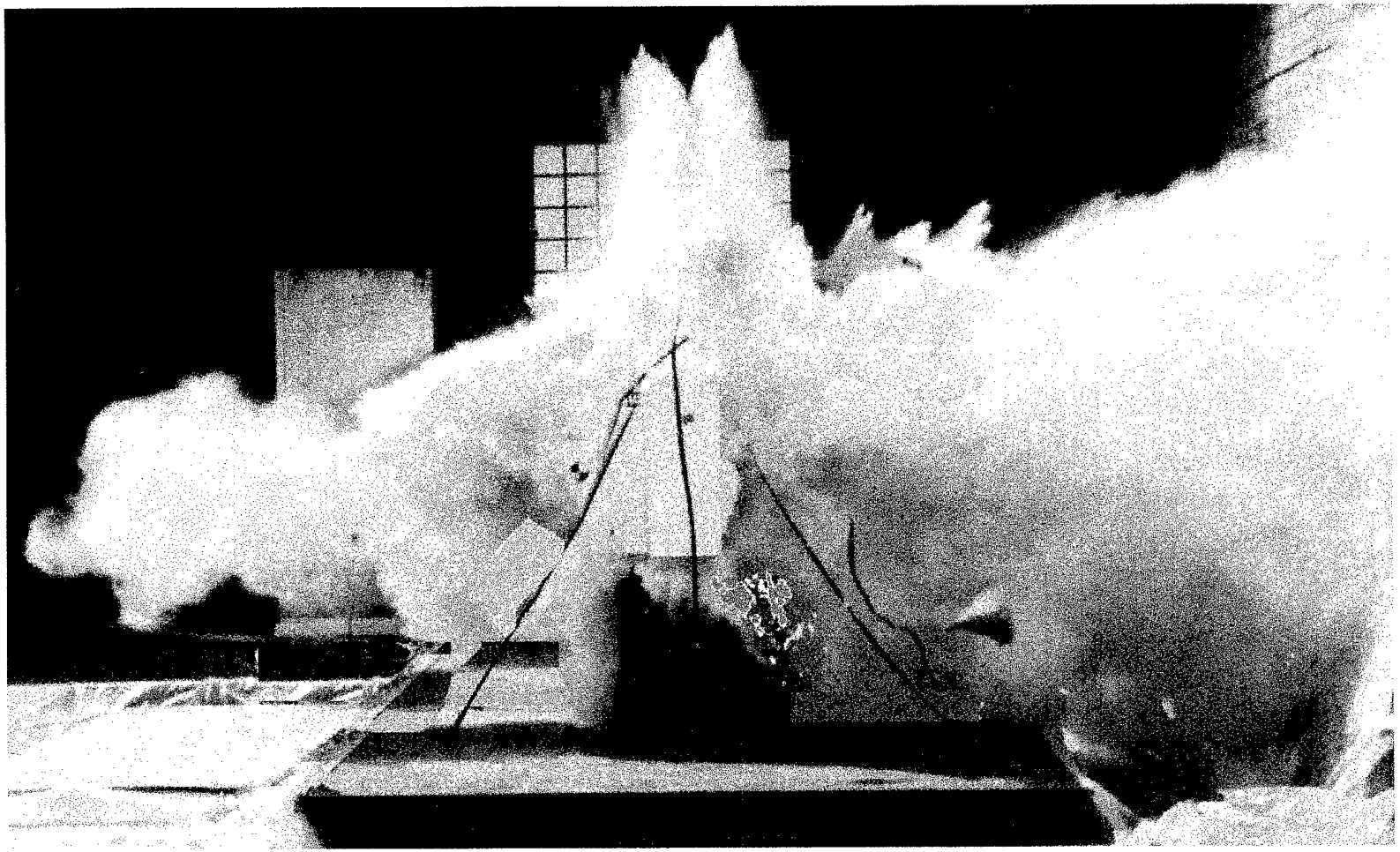


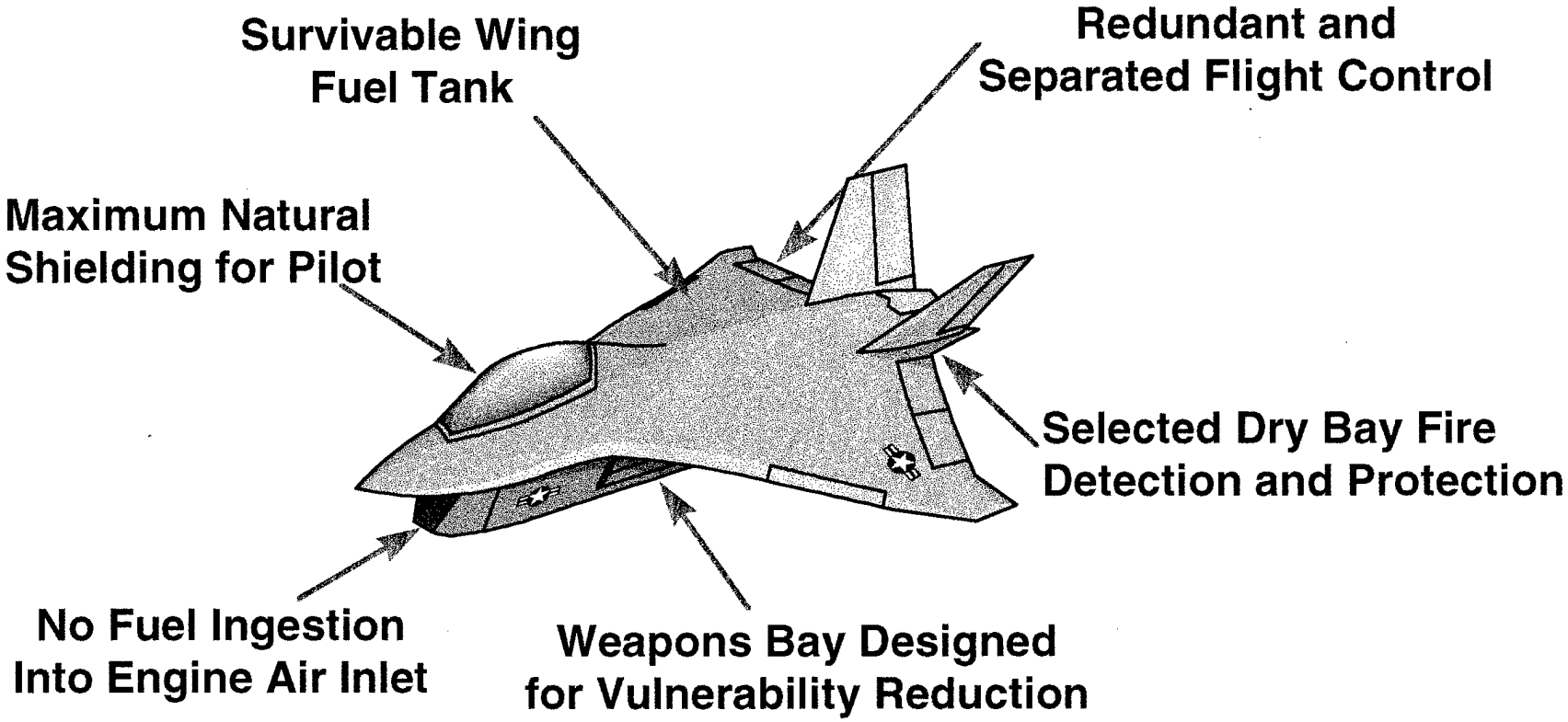
Photo of Event



BOEING

APH / Arnold D / vulnerability / sept 1997

Results of Analysis and Demonstration Testing on PWSC Design



Summary

- JSF objective of Affordability
- Boeing's Approach is to Balance Vulnerability and Susceptibility
- Tools Such as 3D Solids Models, Finite Element Analysis, and Computational Fluid Dynamics will reduce the cost of the JSF Development
- Modeling, Simulation and Testing will reduce risk for the JSF Design
- Analysis, verified by component testing, will justify wavier from full scale "live fire law" test.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